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STRATIGRAPHY OF THE HIEROGLYPHIC BEDS WITH "BLACK EOCENE" FACIES IN THE SILESIAN NAPPE (OUTER FLYSCH CARPATHIANS, POLAND)

Anna WAŚKOWSKA

AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Al. Mickiewicza 30, 30-059 Kraków, Poland; e-mail: waskowsk@agh.edu.pl

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Abstract: The lithologic variation and biostratigraphy of the Hieroglyphic Beds were examined in the Szczyrzyc Depression, where four lithologic complexes were distinguished. The biostratigraphy is based on agglutinated foraminifera and supported by scarce planktonic foraminifera. The lower part of the Hieroglyphic Beds contains non-characteristic, Ypresian foraminifers, including assemblages of small-sized *Trochammina* and at successively higher levels representatives of the Bartonian Ammodiscus latus Zone and the Priabonian Reticulophragmium gerochi Zone. The upper part of the Hieroglyphic Beds, composed of dark shales enriched in TOC (1–2%), corresponds to the deposits of the so-called Black Eocene, known from the Fore-Magura group of nappes. Redeposited flysch rocks resulting from episodes of subaqueous mass flow occur in the lower Bartonian part of the section.

Key words: Eocene, Outer Carpathians, Hieroglyphic Beds, Foraminifera, biostratigraphy, dark shales.

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INTRODUCTION

Thin-bedded shale-sandstone turbidites were widely distributed during the Eocene in the Outer Carpathian basins. Part of these deposits are distinguished as the Hieroglyphic Beds (e.g., Książkiewicz, 1951, 1974; Geroch, 1960; Bieda *et al.,* 1963; Geroch *et al*., 1967; Ślączka, 1971; Burtan, 1973; Morgiel and Szymakowska, 1978; Geroch and Koszarski, 1988; Rajchel, 1990; Ślączka *et al.*, 1991; Cieszkowski, 1992; Szymakowska and Wójcik, 1992; Paul, 1993; Leszczyński and Radomski, 1994; Wójcik and Rączkowski, 1994; Ryłko, 2004; Cieszkowski *et al.*, 2006a; Golonka and Waśkowska, 2007, and references therein), which were deposited in the Silesian, Skole, and the Dukla basins. They were preserved in the sedimentary series of the Silesian and Skole nappes, as well as in the Fore-Magura group of nappes. The Hieroglyphic Beds are characterised by the occurrence of green and grey shales, interbedded with grey quartzose sandstones. In the Silesian Nappe, they occur above the Ciężkowice or Istebna beds and below the Green Shale and the Globigerina Marl (e.g., Geroch, 1960; Bieda *et al.,* 1963; Geroch *et al*., 1967; Książkiewicz, 1974; Ryłko, 2004; Cieszkowski *et al.*, 2006a; Golonka and Waśkowska-Oliwa, 2007; Golonka *et al.,* 2013, and references therein). The name of this distinct division refers to a particular feature, which is the large number of hieroglyphs on the lower surfaces of sandstone beds (Paul and Tietze, 1879; Geroch *et al*., 1967; Czaplicka *et al*., 1968).

The Hieroglyphic Beds of the Silesian Nappe in the Szczyrzyc Depression are developed in a specific facies. They display diversified lithology, which only partly corresponds to the typical development referred to "thin-bedded shale-sandstone flysch" with grey-green shales. The description of these atypical lithofacies and the elaboration of their biostratigraphy on the basis of foraminifera are the main objective of this paper.

STUDY AREA

The studies were conducted in the southern part of the Wiśnicz Foothills of the Carpathians, SE of Kraków (e.g., Starkel, 1972). This area belongs to the Silesian Nappe (Fig. 1), which consists of deep-water Jurassic–Miocene, flysch-type sedimentary series. The Silesian Basin, during its history of about 150 Ma, was periodically subdivided into partly independent smaller basins, separated by intra-basin elevations, the number and size of which changed over time (e.g., Książkiewicz, 1962, 1977; Maheľ, 1974; Cieszkowski *et al.*, 1985; Golonka *et al.*, 2006, 2008, 2013; Golonka and Waśkowska-Oliwa, 2007; Golonka, 2011, and references therein). During the Jurassic–Eocene interval, four

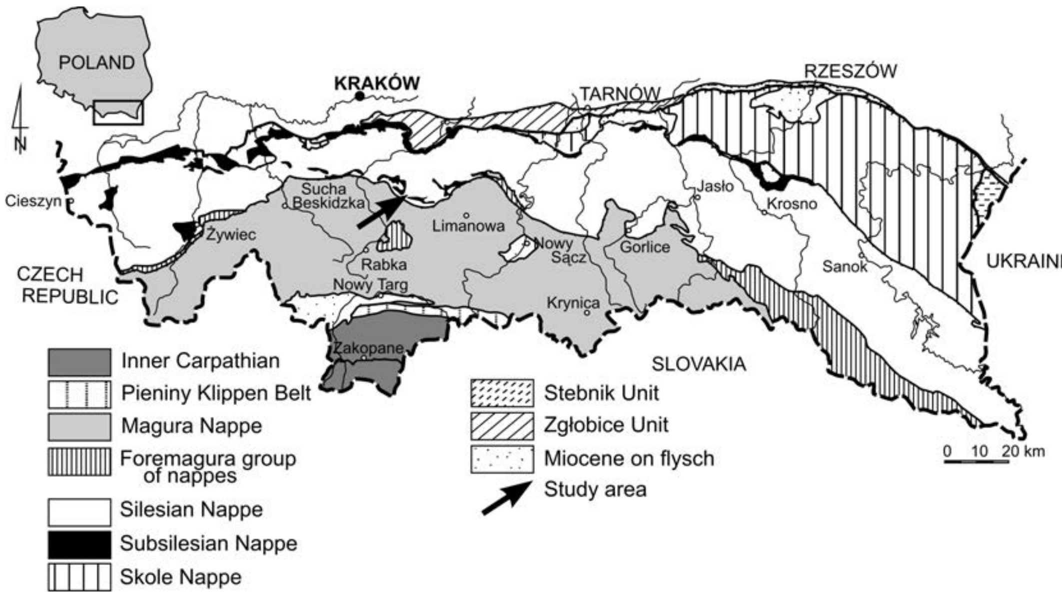


Fig. 1. Geological setting of the study area on the geological map of the Polish Carpathians (modified from Żytko *et al*., 1989).

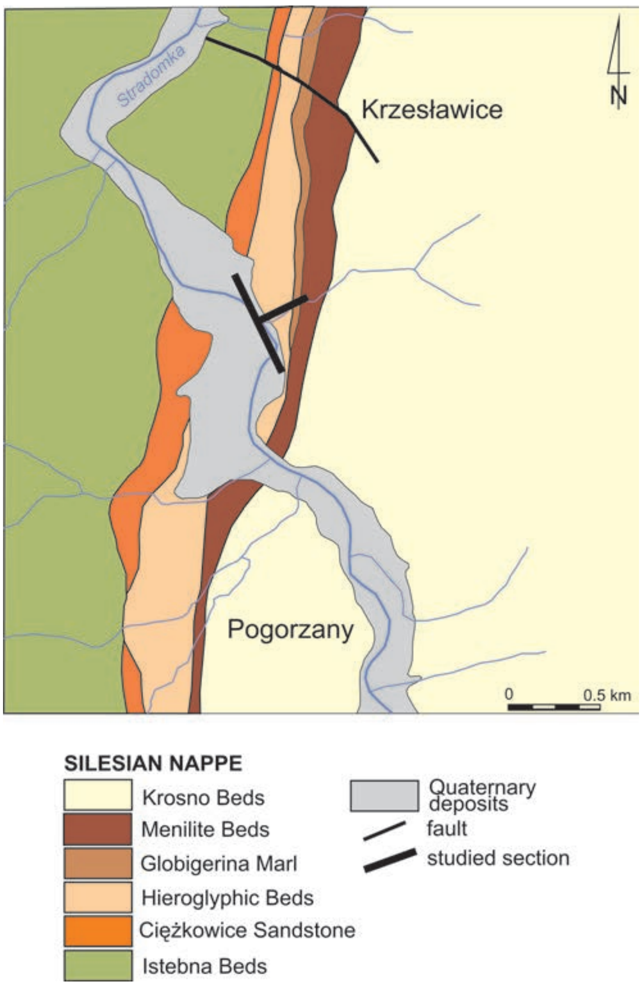


Fig. 2. Geological map of the Krzesławice area (after Chodyń and Waśkowska-Oliwa, 2006, modified).

basins have been distinguished, including the Silesian Basin s.s., which became a part of the Menilite-Krosno Basin in the Late Eocene. During the Miocene, as a result of tectonic movements, the deposits of the Carpathian basins underwent folding, nappe formation and uplift, leading to the creation of the Carpathian Arc (e.g., Książkiewicz, 1962, 1977; Golonka *et al*., 2006; Golonka and Waśkowska-Oliwa, 2007; and references therein).

The study area is situated within the Szczyrzyc Synclinorium (*sensu* Chodyń, 2002; Chodyń and Waśkowska-Oliwa, 2006, Zhang *et al*., 2008) composed of the Cicień-Grodzisko Monocline built of Cretaceous and Palaeocene strata (Burtan, 1974, 1978, 1984), and the Szczyrzyc Depression (Kuźniar, 1924, 1935), where Palaeogene deposits predominate. The Szczyrzyc Depression contains a continuous sedimentary succession of the Silesian Nappe from the Palaeocene part of the Istebna Beds to the Oligocene Krosno Beds (Figs 2, 3).

The Hieroglyphic Beds, studied in the Szczyrzyc Synclinorium, form a meridionally oriented strip stretching along the western edge of the Szczyrzyc Depression, between the villages of Bigorzówka and Skrzydlna. A complete section of Hieroglyphic Beds, including the underlying and overlying strata is exposed near Krzesławice in the valley of the Stradomka river and its tributaries (N49°48'14.33"; E20°10' 25.23"), about 10 km north of Szczyrzyc (Fig. 2). The field work and sampling took place in 2005 and 2009 before the partial regulation of a section of the Stradomka River.

METHODS

The Hieroglyphic Beds section exposed in the Stradomka valley was logged and sampled in detail (Fig. 3). Altogether, 38 samples of shales were collected. Each sample, about 1 kg in weight, underwent the standard procedure of micropalaeontological processing. It was first macerated in an aquatic solution of Glauber's salt, and next washed on

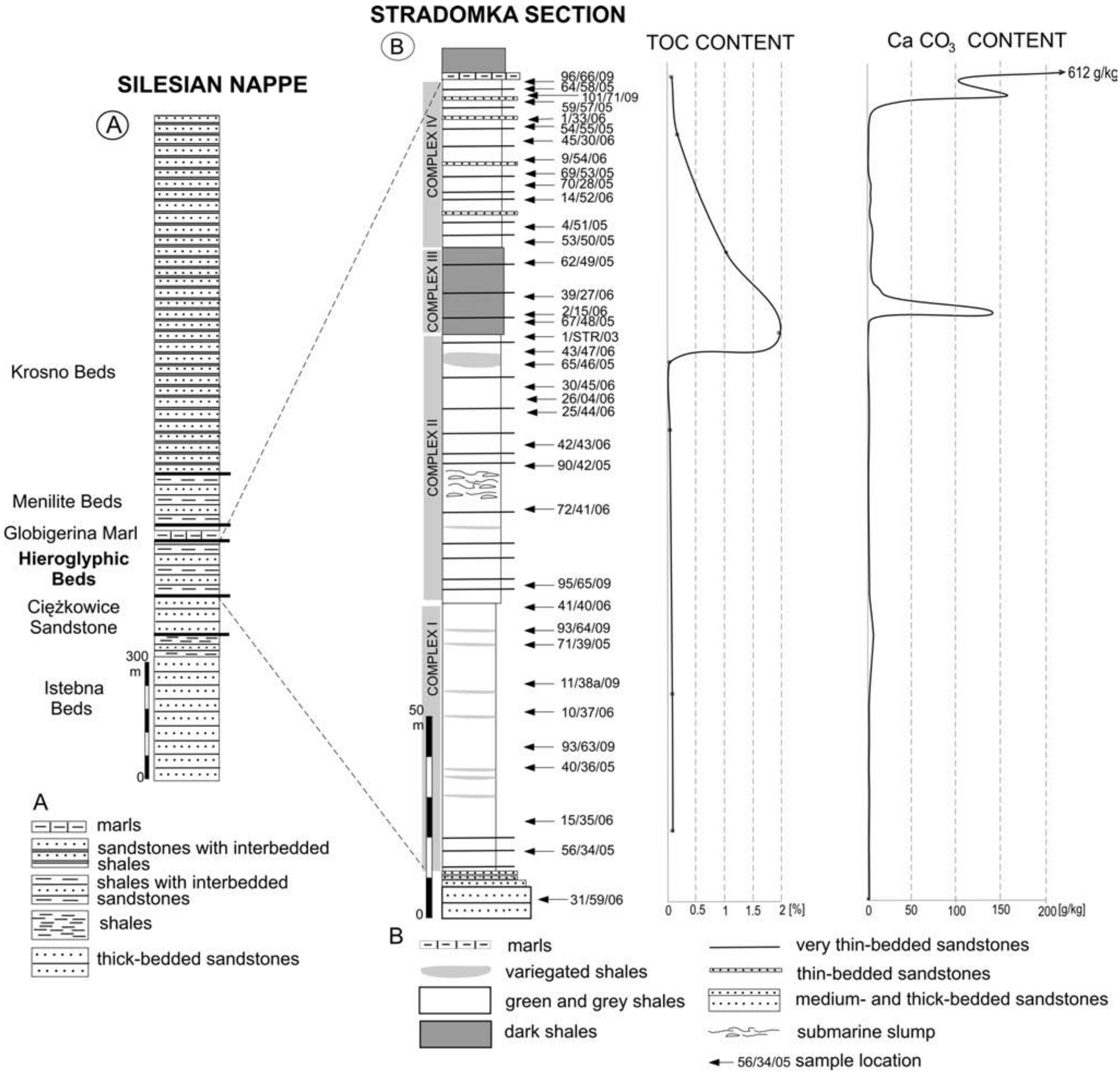


Fig. 3. Position of the Hieroglyphic Beds in Szczyrzyc Depression. **A.** Lithostratigraphic log of the Silesian Nappe (after Chodyń and Waśkowska-Oliwa, 2006 – modified). **B.** Lithologic log of the Hieroglyphic Beds with TOC and carbonate content parameters.

meshes, 0.68 mm in diameter. Later, the microfossils were separated from the clastic residue. In the micropalaeontological material obtained, the tests of foraminifera predominated. The accessory components included fish teeth, echinoid spines, and ostracods. The foraminiferal tests were taxonomically determined and analysed under a Nikon VL 100POL binocular microscope in the Department of General Geology and Geotourism of AGH WGiOŚ. Photographic documentation was done using a Nikon Digital SIGHT DS-Fi1 camera, and a FEI QUANTA 200 FEG sca- nning microscope in the Scanning Microscopy Laboratory of WGiOŚ AGH.

The petrography of the Hieroglyphic Beds was microscopically examined in 10 thin sections with the use of a Nikon ECLIPSE LV 100 POL microscope. Thirty samples were analysed for carbonate content, using the Scheibler volumetric method, in the Trace Element Analysis Lab of the WGiOŚ AGH. In 10 samples, the TOC content was analysed in the Department of Geology and Geochemistry of the Oil and Gas Institute – National Research Institute, by using Rock Eval pyrolysis.

The analyzed materials were deposited in the author’s collection at the Department of WGiOŚ AGH, in the ‘Krzesławice’ section.

RESULTS

Lithology

The Hieroglyphic Beds of the Szczyrzyc Depression are developed as a series of thin-bedded shaly-sandy turbidites, about 180 m thick, with a fairly diverse range of lithologies (Figs 4, 5). Green and grey shales which form the thickest homogeneous packages predominate. Brown shales and mudstones are common, and dark brown shales resembling those of the Menilite Formation (Oligocene) and red shales occur as intercalations. Sandstones are mostly grey, thin-bedded and fine-grained, usually with parallel or wavy lamination, accentuated by darker or slightly finer grains. They consist mainly of quartz (Fig. 6A), and an admixture of glauconite, muscovite, feldspar and heavy minerals. In the majority of these sandstones beds, bioglyphs occur on their lower surfaces. The sandstone beds are very diverse with regard to bed thickness and grain size, as well as in the type and abundance of sedimentary structures. Thin layers of bentonitised tuffites, as well as siderites, marls, and manganese concretions, are additional components. The deposits studied are subdivided into complexes characterized by similar lithology. From the base, they are as follows: (I) green shales, (II) green shales with sandstones, (III) brown-grey shales with bentonites ("Black Eocene"), and (IV) grey shales with sandstones (Figs 4, 5).

Contact with underlying deposits

The Hieroglyphic Beds overlie the Ciężkowice Sandstone, the uppermost part of which is dominated by medium- and thick-bedded, fine- to medium-grained sandstones. The transition to the Hieroglyphic Beds occurs in an interval about 3m thick. In this transitional interval, a gradual reduction in thickness of the sandstone layers, as well as an increase of the thickness and frequency green and grey-green shales can be observed (Fig. 4).

Complex I: green shales

The lower part of the Hieroglyphic Beds, approximately 70 m thick, is made up of green and grey-green shales (Figs 4, 7A, B). These are strongly bioturbated (Fig. 6B), and relatively soft. Several intercalations of soft red shales, the thickness of which is from several to 40 cm, were observed here (Figs 7C, 4C). The first red shale package appears 13 m above the base of the complex. The higher packages of the red shales occur irregularly (Fig. 4). The highest accumulation of red shale interbeddings occurs in the upper part of the complex I, from 66–69 m above the base of the Hieroglyphic Beds. In the upper and basal parts of the complex I, grey fine-grained quartzose sandstones are present (Fig. 4). The carbonate content is from 0.1% to 0.3%wt of rock and the TOC ranges from 0.04% in the red shale to 0.94% in the green shale (Fig. 3).

Complex II: green shales with sandstones

Complex II is about 80–90 m thick and is characterized by the occurrence of green and grey-green laminated shales, which are its predominant lithotype (Fig. 4). The shales contain interbedded quartzose sandstones. In the middle and upper parts of complex II, very thin-bedded, and rarely medium-bedded sandstones occur, with parallel, or parallel and wavy lamination (Fig. 7E). In the uppermost part, thin-bedded layers of brown, medium-hard mudstones are present (Fig. 7G); some of them contain fine-grained sand, and a little above them – thin-bedded, fine-grained brown sandstones occur in isolated layers. In the upper part of complex II (150 m above the base of the succession), variegated shales are an accessory component (Fig. 5). These are packets of grey-green shales, thinly laminated by red shales (Fig. 7F). Some of the sandstones within the variegated shales occur in the form of thin (up to 3 cm thick) and long (3–7 m) lenses. The packet containing variegated deposits is about 5 m thick. In the uppermost part of complex II, a 22-cm- thick layer of soft, blue claystone, and a horizon with concretions occur. The whole complex is bioturbated (Fig. 6D). The deposits of complex II are fairly poor in organic carbon, the amounts of which fluctuate from 0.38% in the grey-green shales to 0.03% in the variegated shales (Fig. 3).

Within complex II, 10-m-thick chaotic deposits of a submarine slump occur. They contain soft (partly macerated), plastically deformed green shales, which contain chaotically distributed cobbles and boulders of sandstones and clasts of shales (Figs 3, 7D). Shale clasts predominate in the slump matrix. The sandstone clasts have polished surfaces like slickensides and are poorly rounded. The shale clasts are elongated, generally lens-shaped and irregularly distributed, with sizes varying from several centimetres to more than one metre. In terms of lithology, they are represented mostly by green and grey-green laminated shales (similar to the shales of the Hieroglyphic Beds), as well as by grey and dark grey shales (similar to the shales of the Istebna Beds), packets of thin- bedded flysch, and fragments of grey, quartzose, fine- and medium-grained sandstones.

Complex III: brown and green-grey shales with bentonites

Starting from the 180th m above the base of the Hieroglyphic Beds, the next 20 m of the section is characterised by the presence of dark shales, which – apart from grey-green and green shales – are the principal lithotype there (Waśkowska-Oliwa *et al*., 2008; Fig. 7). These are thinly laminated shales with characteristic brown and brown-grey colouration (Figs 6F, 8A, C), with limonite staining on the planes of jointing. The brown shales are interbedded with grey-green shales.

The characteristic element for this complex is the occurrence of bentonitic clays (Chodyń and Waśkowska-Oliwa, 2006; Figs 5, 8B). Their pyroclastic origin is confirmed by X-ray analyses (R. Chodyń, pers. comm.). They are soft, creamy or grey creamy in colour, rarely slightly pinkish. In complex III, bentonites occur in the form of thin (1–3 mm thick) laminae, or merge with the surrounding deposits in packets 0.5–2 m thick. Dark and grey-green shales containing numerous interbedded bentonitic laminae occur in intervals of ten or so millimetres. Between these packets, the bentonitic laminae appear irregularly and much less frequently.

The next lithotypes, occurring subordinately in complex III, are moderately hard, brown mudstones and sandy mudstones, massive or parallel-laminated (Fig. 5). Some of them contain muscovite and some are marly. Apart from the mudstones, grey, thin- and very thin- bedded quartzose sandstones (with parallel or, rarely, wavy lamination), as well as very thin-bedded, very fine-grained, quartzose sandstones with a characteristic brown colour, usually containing muscovite, also occur there. In the upper part of the

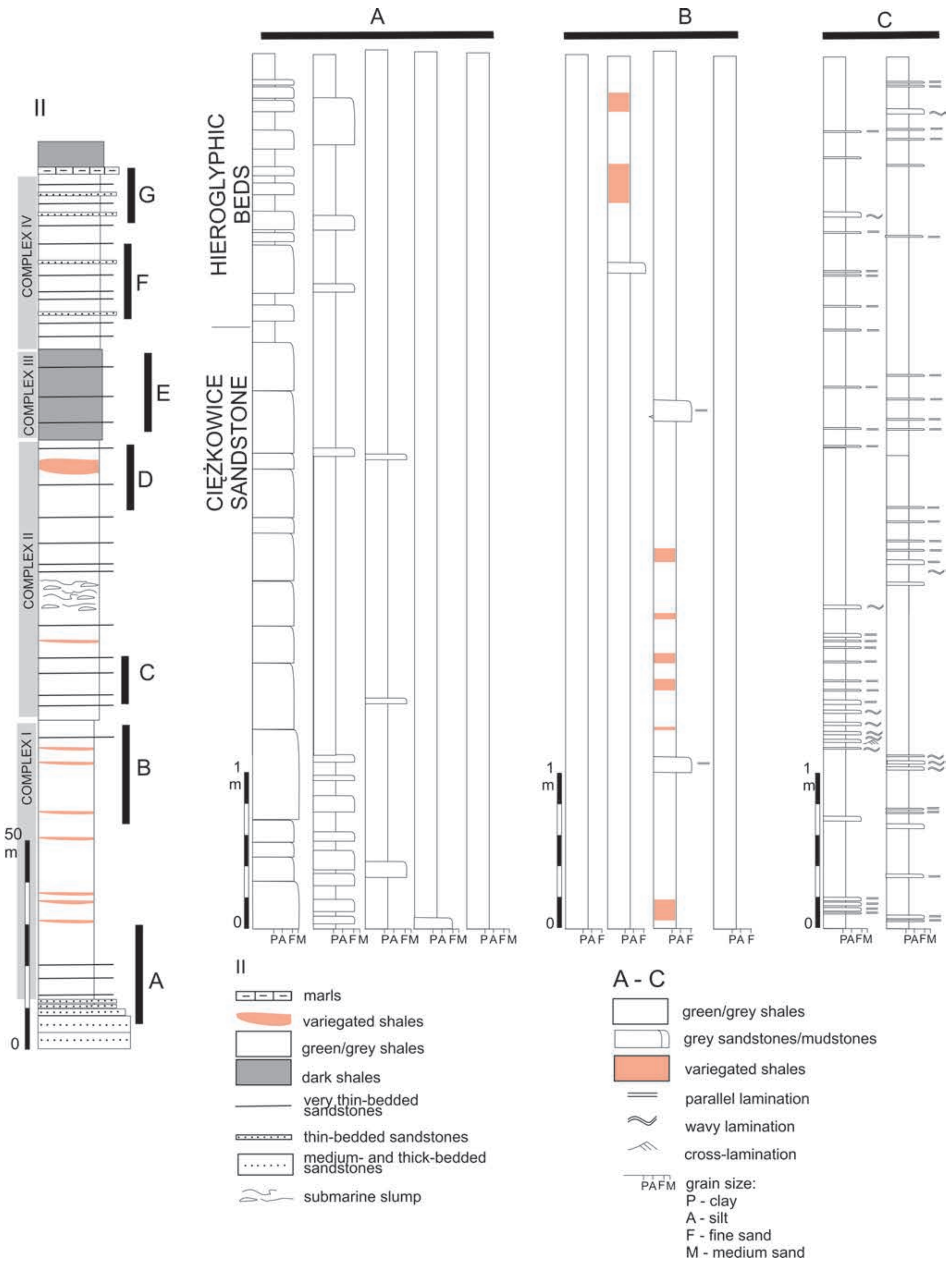


Fig. 4. Detailed lithologic logs of the lower part of Hieroglyphic Beds. Intervals A–C are marked in the schematic log of the Hieroglyphic Beds (II).

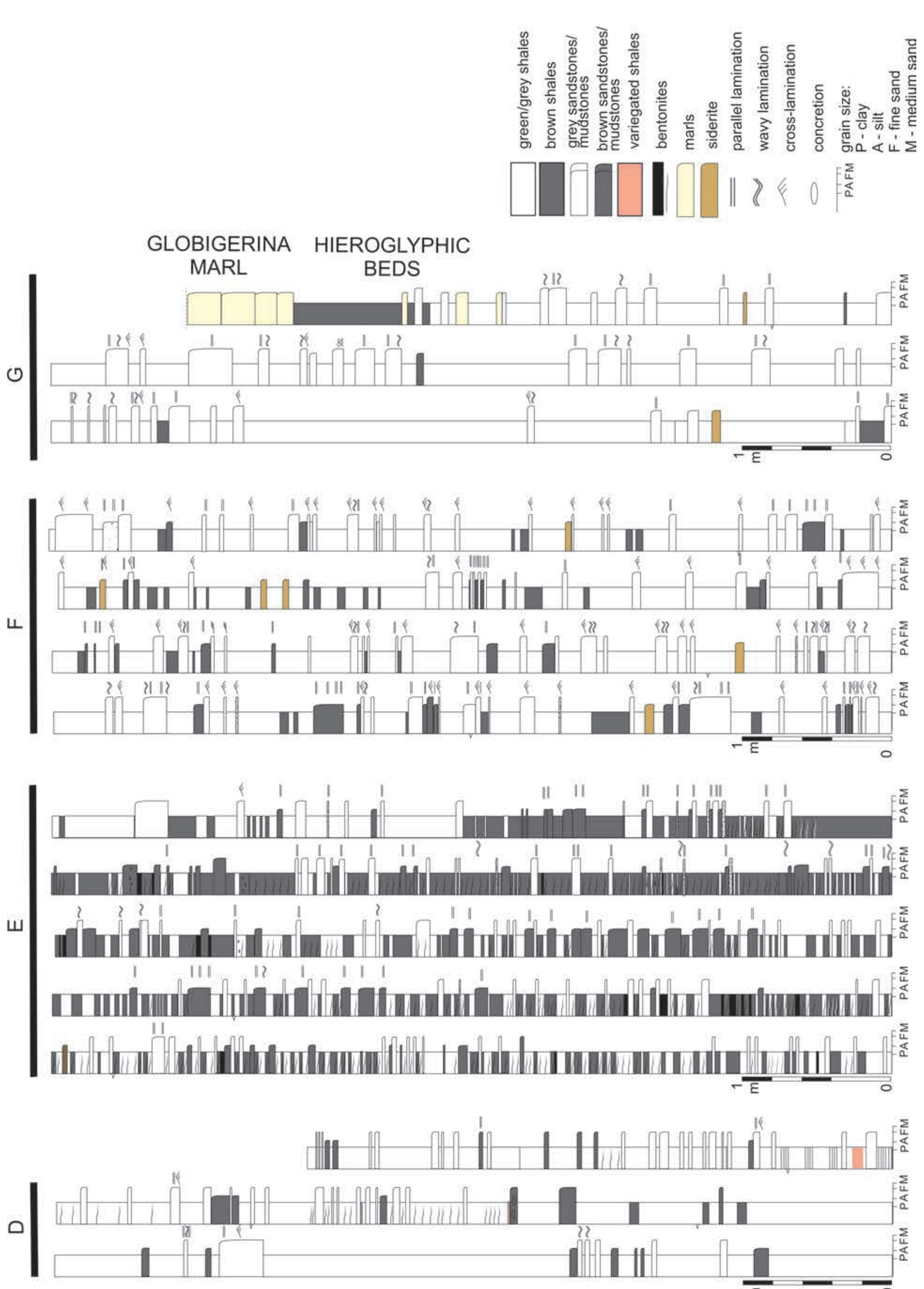


Fig. 5. Detailed lithologic logs of the upper part of Hieroglyphic Beds. Intervals D–E are marked in the schematic log of the Hieroglyphic Beds (II) in Fig. 4.

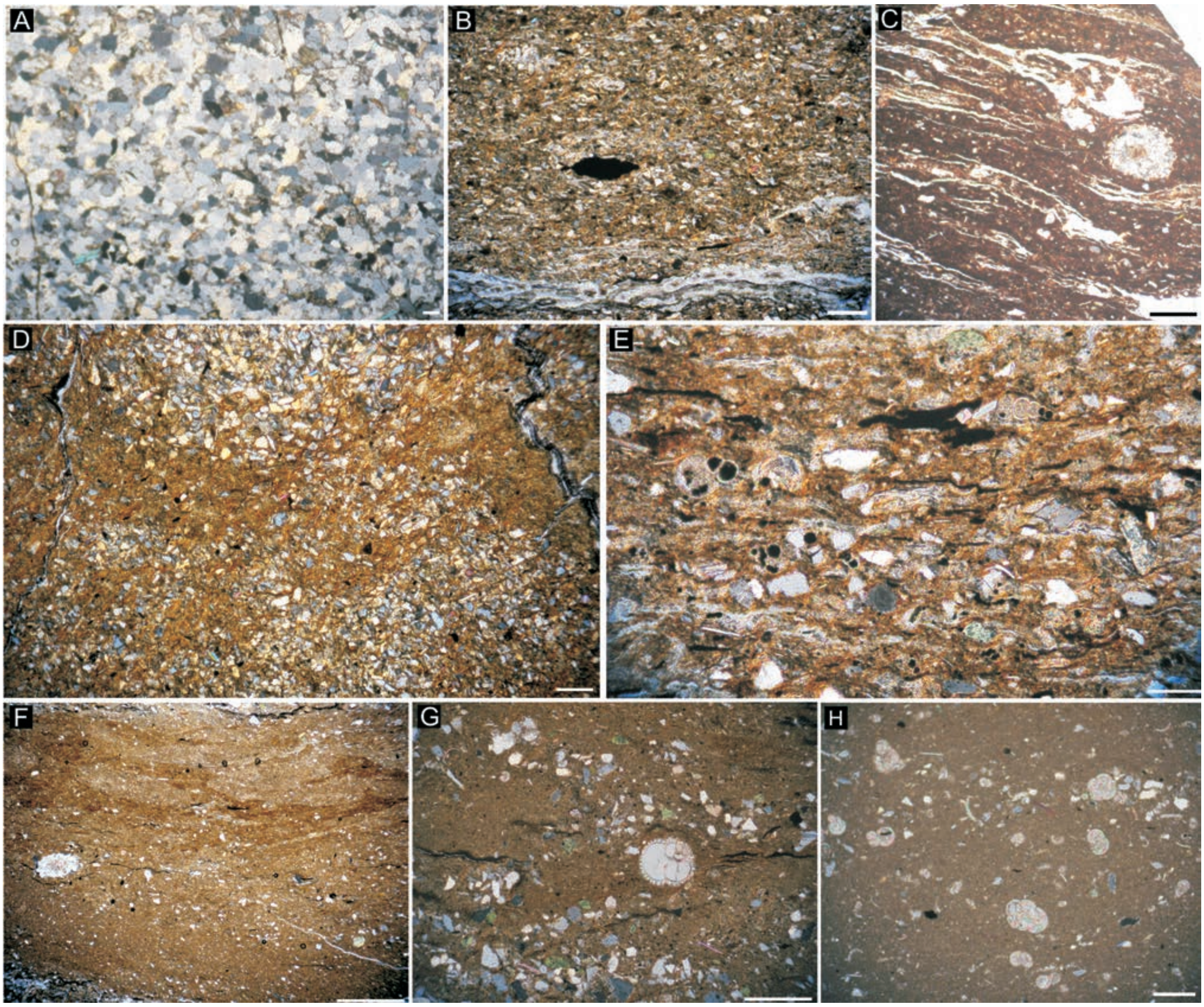


Fig. 6. Thin-sections of the Hieroglyphic Beds deposits. Scale bar = 100 µm. **A**. Quartzose sandstone (complex II). **B**. Bioturbated shale with *Bathysiphon* sp. test (complex I). **C**. Variegated shale (complex I); white fields are breaks in the thin-section. **D**. Bioturbated shale (complex II). **E**. Shale with redeposited calcareous bioclasts (complex II). **F**. “Black Eocene” dark shale with *Bathysiphon* sp. test. **G**. Marl with “*Globigerina*-type fauna” (complex IV). **H**. Globigerina Marl.

complex, massive, dark, almost black mudstones with manganese mineralisation occur, along with very similar sandy mudstones. Also levels containing manganese concretions were observed (Fig. 5).

Within the Hieroglyphic Beds, these deposits are the richest in organic carbon. The TOC content is 1–2%. In terms of carbonate content, these deposits show great diversity. As a rule, this content is low, from 0.2% to 0.6% wt of a sample; in isolated beds of dark, calcareous mudstones, it may abruptly increase to 14% wt of sample (Fig. 3).

Complex IV: grey-green shales with sandstones

This complex is dominated by grey-green, bioturbated shales, with thin- and medium-bedded, fine-grained, parallel-laminated sandstones, as well as sandy mudstones (Figs 4, 8D, E, G). The proportion of sandstones increases gradually towards the top of the section and more coarse-grained layers appear among the sandstones; additionally, a single beds of conglomerate occur too. The brown mudstones and shales are interbedded here subordinately, and brown sandstones occur sporadically. In the uppermost part of the Hieroglyphic Beds, brown shales of Menilite-type, and lenses of sphaerosiderite were found (Fig. 8F). In the lower part of complex IV, the carbonate content is low, and amounts from 0.2% to 1.1% wt of the rock, while in the uppermost part it increases to 45% wt (Fig. 3). In thin sections of shales, relatively numerous tests of the foraminiferid *Bathysiphon* were found in the *in situ* position, and relatively well preserved tests of planktonic foraminifera occur (Fig. 6F, G). The tests are distributed irregularly.

Contact with overlying deposits

The sedimentary contact with the overlying Globigerina Marl is well defined in the section. The transition zone is about 1.5 m thick. In the lower part, along with grey-green shales typical of the Hieroglyphic Beds, there are several thin, isolated beds of marls similar to the Globigerina Marl (Fig. 5). In thin sections, planktonic foraminifers were obser-

Fig. 7. Outcrop details showing the lithology of the Hieroglyphic Beds. The hammer (scale) is 30 cm long. **A**, **B**. Green and grey shales of complex I. **C**. Variegated shales in upper part of the complex I. **D**. Submarine slump in complex II. **E**. Thin-bedded shaly-sandy deposits of the complex II. **F**. Variegated shales in upper part of complex II. **G**. Green-grey shales intercalated by dark shales in upper part of complex II.

ved (Fig. 6G). The grey-green shales are replaced by brown, thinly laminated Menilite-type shales, about 1 m thick. Above the transitional shale interval, the Globigerina Marl begins. It is a compact series of grey, hard, marly limestones, weathering white. They form thin- and medium-bedded, internally massive layers. The total thickness of the Globigerina Marl is up to several metres and they are overlain by the Menilite Beds (Menilite Formation), dominated by brown shales.

Foraminiferal assemblages

Numbers, structure, and preservation

All of the collected samples contained foraminiferal tests. The number of specimens was diversified and usually varied from 500 to 2500 per sample, or sometimes even higher.

Agglutinating foraminifers predominate. Their state of preservation is fairly good. Calcareous, planktonic and benthic foraminifera occur irregularly. In complexes I–III, they were noted as accessory components and usually do not exceed 1% of all foraminifera (af). The state of preservation of plankton is poor; the tests show traces of corrosion. Calcareous benthos is slightly better preserved. Sample No. 2/15/06 from complex III (Fig. 9) is an exception. The fairly well preserved benthic calcareous fauna predominates in this sample and together with plankton constitutes 88% af. The subsequent sample, No. 39/27/06, contains increased number of calcareous foraminifera (Fig. 9) amounting to 7.2% af. In this part of the section, there is an evident increase in the carbonate content up to 140 g/kg of rock, whereas in complexes I–III it ranges, as a rule, from 1 to 11 g/kg of rock (Fig. 3). The number and diversity of plankton increase

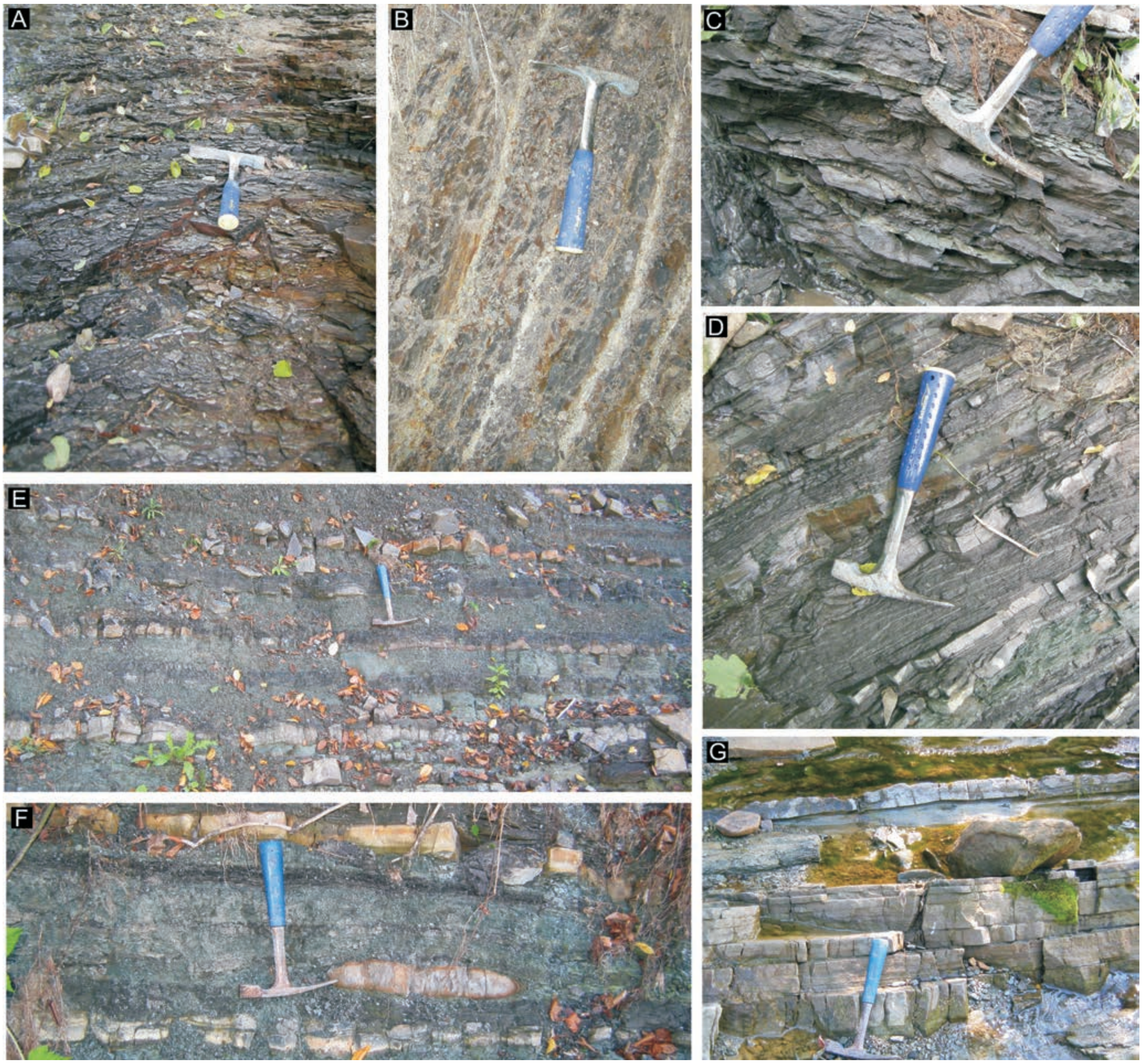


Fig. 8. Outcrop showing details of the lithology of the Hieroglyphic Beds. The hammer (scale) is 30 cm long. **A**. "Black Eocene" deposits (complex III). **B**. Thin bentonite layers in dark shales in complex III. **C**. "Black Eocene" deposits (complex III). **D**, **E**. Thin-bedded turbidites of complex IV. **F**. Sphaerosiderite in thin-bedded turbidites of complex IV. **G**. Medium-bedded sandstones in upper part of complex IV.

in the uppermost part of the section. In complex IV, planktonic forms are a common component, and their shares range from 1% to 2%, whereas in the topmost part, in the final metres of the section, the amount of calcareous foraminifera increases abruptly to more than 10%, with the calcareous foraminifera dominated by plankton. This structure of the assemblage is accompanied by a rapid and substantial increase in carbonate content, which rises dynamically to a value 16% wt of rock. In the lower part of complex IV, however, it is variable and fluctuates from 0.4% to 3% wt of rock (Fig. 3).

Biostratigraphy

The age of sedimentation of the Hieroglyphic Beds was estimated on the basis of the agglutinating foraminifera. They were dominated by an uncharacteristic cosmopolitan fauna. It was possible to establish the time frame of sedimentation, only thanks to the analysis of continuous sequences, because the taxa that were stratigraphic markers occurred sporadically (Fig. 9). In connection with the fact that planktonic forms occur highly dispersed and the biostratigraphic data obtained on the basis of them is spot-specific, the biostratigraphic division was based on agglutinating foraminifera.

Rzehakina fissistomata Zone

The foraminiferal assemblages in the lower part of the Hieroglyphic Beds contain chiefly long-ranging species without stratigraphic marker forms (see below). Thus, in order to establish the age of the bottom part of the Hieroglyphic Beds, the material for analyses was collected from the uppermost part of the Ciężkowice Sandstone, namely sample No. 31/59/06 (Fig. 9), where the fauna included single specimens of *Rzehakina fissistomata* (Grzybowski). It is a characteristic taxon with significance as a marker for the Palaeocene in the Carpathian flysch (e.g., Jurkiewicz, 1967; Jednorowska, 1968, 1975; Morgiel and Szymakowska, 1978; Morgiel and Olszewska, 1981; Geroch and Nowak, 1984; Olszewska *et al*., 1996; Olszewska, 1997; Bąk, 2004; Waśkowska-Oliwa, 2005, 2008, and citations therein). Additionally, a number of other species, which are typical components of Palaeocene assemblages, were present, e.g., *Rzehakina epigona* (Rzehak), *Caudammina gigantea* (Geroch), *Caudammina ovula* (Grzybowski), *Hormosina* cf. *velascoensis* (Cushman), and *Glomospira diffundens* Cushman et Renz. The foraminiferal assemblage from the uppermost part of the Ciężkowice Sandstone thus represents the Palaeocene and following the integrated zonations for the Outer Carpathians, is unambiguously classified in the Rzehakina fissistomata Zone (Fig. 9).

Assemblage of cosmopolitan foraminifera with intervals of *Trochammina* assemblages

In complex I and the basal part of complex II, the assemblages contained almost exclusively cosmopolitan, long-ranging species, commonly occurring in the Carpathian flysch in the Cretaceous and Palaeogene, without biostratigraphic significance. These included, e.g., *Bathysiphon*, *Nothia* (10–40% af, max. 75% af), *Rhabdammina* and *Psammosiphonella* div. spp. (usually up to 10% af, max. 62%), *Paratrochamminoides* and *Trochamminoides* (5–10% af, max. 18%), *Karrerulina* (1–7% af, max. 13.5% af), *Haplophragmoides* (2–6% af, max. 11.5% af), *Recurvoides* and *Thalmannammina* (3–10% af, max. 40% af), *Ammodiscus* div. spp. (with the exception of *Ammodiscus latus* Grzybowski; from 1–4% of agglutinated foraminifera on average (ag), max 15% ag), as well as *Reophax*, *Subreophax*, *Ammosphaeroidina pseudopauciloculata* (Mjatliuk), and *Saccammina* (Figs 10–12). Among these taxa, the forms known from the Eocene, i.e., *Eratidus gerochii* Kaminski et Gradstein, *Haplophragmoides nauticus* Kaminski *et al.* and *Pseudonodosinella elongata* (Grzybowski), occurred irregularly (Figs 9, 13).

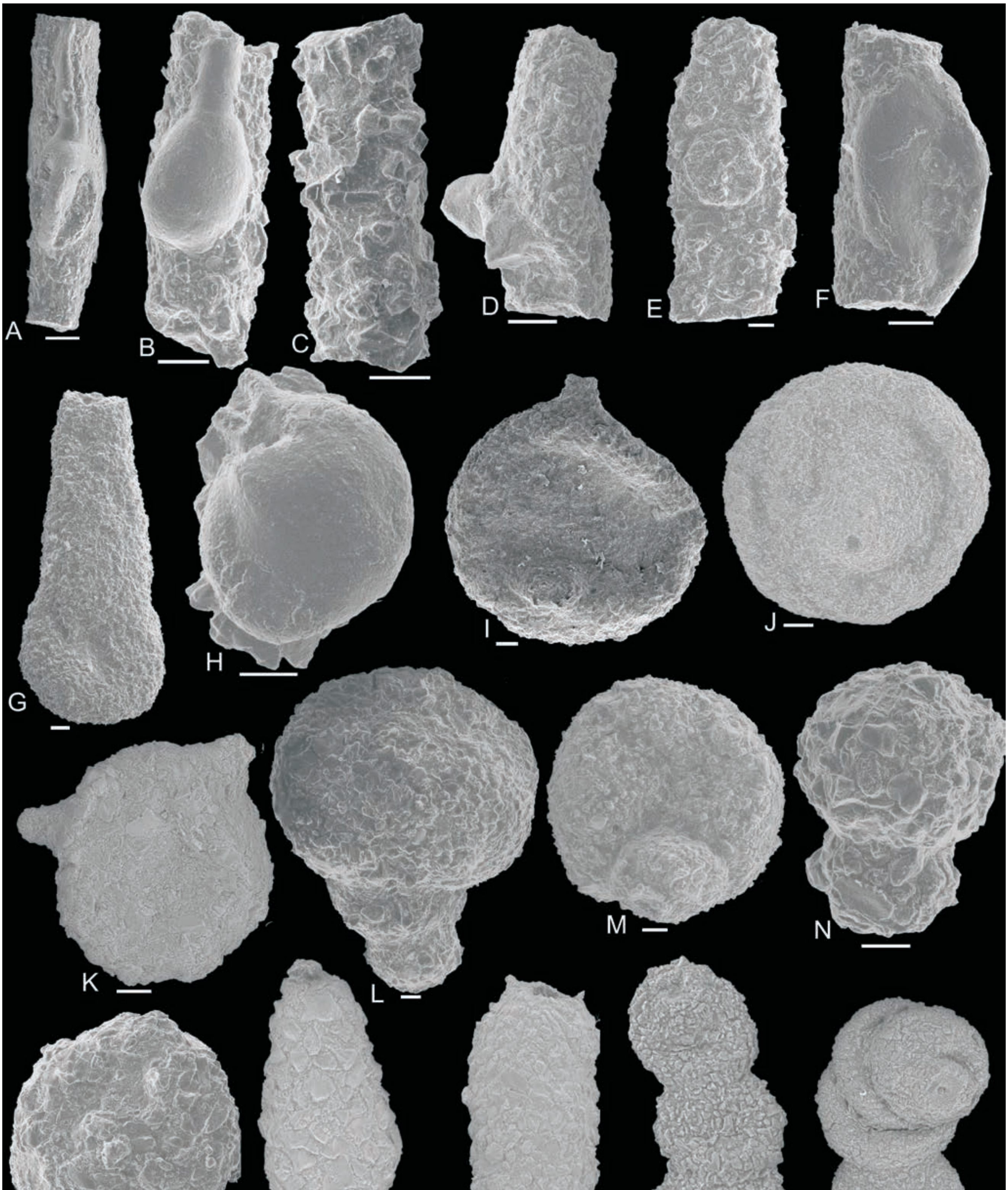
The characteristic feature of the assemblages in the upper part of complex I was the presence of numerous *Trochammina* (Waśkowska, 2012, 2014a) occurring in amounts of up to 80% af. An increase in *Trochammina* number was observed in deposits about 50 m thick interval in the upper part of complex I, in several subsequent samples, from 40/36/05 up to 95/65/09 (Fig. 9). In the upper part of complex I (sample 93/64/09), *Saccamminoides carpathicus*? Geroch was identified. It is the index taxon for the upper Ypresian, characterised by a narrow stratigraphic range in the Outer Carpathians (e.g., Jednorowska, 1968; Morgiel and Szymakowska, 1978; Geroch and Nowak, 1984; Olszewska *et al*., 1996, Olszewska, 1997, Waśkowska, 2011a, and references therein). More than 10 m below the deposits with *Saccamminoides carpathicus*? Geroch, in the middle part of complex I, a single specimen of *Reticulophragmium amplectens* (Grzybowski) was found (Fig. 9). In the Outer Carpathians, it appears near the top of the Lower Eocene (Olszewska, 1997) and just below the last occurrence of *Saccamminoides carpathicus* Geroch; these taxa co-occur only in the upper Ypresian (Morgiel and Olszewska, 1981; Geroch and Koszarski, 1988; Olszewska *et al.*, 1996; Olszewska, 1997; Kaminski and Gradstein, 2005; Cieszkowski *et al*., 2006b; Waśkowska, 2011a, b).

In the shales with small-sized *Trochammina*, single planktonic foraminifera occur. S*ubbotina hornibrooki* (Brönnimann), known from the early Ypresian (Pearson *et al.*, 2006 and citations therein), was identified in sample 93/63/09 (Fig. 9). *Subbotina yeguaensis* (Weinzierl et Applin), *Subbotina corpulenta* (Subbotina), *Subbotina linaperta* Finlay, *Subbotina hagni*? (Gohrbandt) and *Catapsydrax unicavus* Bolli occur in the uppermost part of complex I and the lowermost part of complex II (Fig. 9). These are the so-called large planktonic forms, characteristic of the Eocene, the first appearances of which have been noted in the Lower Eocene, mostly in the upper Ypresian (Pearson *et al*., 2006, and citations therein). The co-occurrence in one assemblage (sample No. 93/64/09) of early Eocene *Saccamminoides carpathicus*? Geroch, and *Subbotina yeguaensis* (Weinzierl et Applin), the time range of which is estimated to be the late Ypresian–Eocene/Oligocene, together with *Subbotina corpulenta* (Subbotina) known from the highest Ypresian–lower Oligocene, is diagnostic for the upper Ypresian age of the uppermost part of complex I. The assemblage of cosmopolitan foraminifera occurs in complexes I and II (Fig. 9).

Ammodiscus latus Zone

In the foraminiferal assemblage in the uppermost part of complex II, *Ammodiscus* (Dolgenia) *latus* Grzybowski was present, accompanied by numerous *Reticulophragmium amplectens* (Grzybowski), (Fig. 11). It constituted up to 20% af. *Ammodiscus latus* Grzybowski (Fig. 11) was an accessory component, except for samples 67/48/05 and 70/28/05, where it constituted up to more than 1.5% af. In the Carpathian flysch, *Ammodiscus latus* Grzybowski is an index taxon for the Bartonian between the first occurrences of *Ammodiscus latus* Grzybowski and *Reticulophragmium gerochi* Neagu *et al.* (= *Reticulophragmium rotundidorsatum* (Hantken) in the older nomenclature; see Neagu, 2011) as reported by Geroch and Nowak (1984), Olszewska *et al.* (1996) and Olszewska (1997; Fig. 13). *Haplophragmoides parvulus* Blaicher, a species characteristic of the Middle and Upper Eocene in the Carpathians (Blaicher, 1961; Malata, 1981; Olszewska *et al*., 1996; Golonka and Waśkowska, 2011, 2012, and references therein) was an accessory component as well as *Buzasina pacifica* (Krasheninnikov) and *Ammomarginulina aubertae* Gradstein et Kaminski. In the uppermost part of the Hieroglyphic Beds, *Spirosigmoilinella compressa* Matsunaga occurred (Figs 11–13). The rare Eocene species include *Eggerelloides propinqus* (Brady), and *Ammogloborotalia* aff. *subvesicularis* (Hanzlikova) (Figs 12, 13). The cosmopolitan forms (listed for complex I) were a permanent component of assemblages, in slightly variable proportions. The number of *Ammodiscus* decreases, and the proportions of *Bathysiphon* and *Nothia*, *Haplo-*

Fig. 9. Biostratigraphy and distribution of the biostratigraphically important taxa against lithologic log of the Hieroglyphic Beds in the Szczyrzyc area.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phragmoides, *Paratrochamminoides* and *Trochamminoides* increased. A clear increase in *Spiroplectammina spectabilis* (Grzybowski) was noted in the upper part of the Ammodiscus latus Zone. A significant drop in the numbers of *Trochammina,* an accessory component, usually amounting to less than 1% af, was observed.

In the lowermost part of complex III (sample 2/15/06; Fig. 9), planktonic foraminifera were found. These forms, which lasted to the early Bartonian and are characteristic of the Early Eocene, occurred together with the typical Late Eocene forms appearing during the late Lutetian. *Jenkinsinia columbiana* (Howe), *Subbotina crociapertura* Blow, and *Acarinina bullbrooki* (Bolli) had their last occurrences at about 40 Ma, while *Subbotina angiporoides* (Hornibrook), *Turborotalia cerroazulensis* (Cole), *Acarinina medizzai* (Tourmarkine), and *Pseudohastigerina wilcoxensis* (Cushman et Ponton) were noted up to about 42 Ma (Fig. 14). *Globoturborotalia ouachitaensis* (Howe et Wallace) and *Globigerina officinalis* Subbotina appear during 44–43 Ma (Pearson *et al*., 2006, and citations therein). Therefore, according to the scale by Gradstein *et al*. (2012), the assemblage of planktonic foraminifera from sample 2/15/06 indicates a late Lutetian age. In this sample, a rich assemblage dominated by calcareous foraminifera (constituting 88% af.) was identified with benthic foraminifera predominant, chiefly of the genera *Cibicides, Eponides*, and Globocassidulina. The assemblages of the Ammodiscus latus Zone occurred in the upper part of complex II, in complex III, and in the lower part of complex IV (Fig. 9).

Reticulophragmium gerochi Zone

In the uppermost part of the Hieroglyphic Beds, beginning with sample 45/30/06 (the final 20 m), a single *Reticulophragmium gerochi* Neagu *et al.* was found (Fig. 9). *Reticulophragmium gerochi* Neagu *et al.* co-occurs with *Ammodiscus latus* Grzybowski and *Reticulophragmium amplectens* (Grzybowski). An increased taxonomic diversity of agglutinating foraminifera was observed in the assemblages.

The final several metres of the Hieroglyphic Beds showed an increased carbonate content of up to 16% wt of the rock (Fig. 3), and – in the foraminiferal assemblages – the numbers of calcareous foraminifera increased successively, with the predominance of planktonic foraminifera. The most numerous assemblages were found in the uppermost part of the section, just below the Globigerina Marl, although their taxonomic diversity was not high and was limited to a few species (Fig. 9). In the planktonic assemblage, apart from long-ranging taxa, there were forms occurring exclusively in the Eocene, i.e., *Subbotina linaperta* (Finlay), *Subbotina corpulenta* (Subbotina), and *Globigerinatheka index* (Finlay), as well as forms appearing in the Late Eocene, and occurring commonly in Oligocene, i.e., *Catapsydrax dissimilis* Cushman et Bermudes, and *Turborotalia increbescens* (Bandy) (Fig. 14). The co-occurrence of these species is dated as the interval between 34 and 38 Ma (Pearson *et al*., 2006, and citations therein) and according the Geological Time Scale (Gradstein *et al*., 2012) corresponds to the Priabonian. The assemblage was marked in the upper part of complex IV (Fig. 9).

DISSCUSSION

Biostratigraphic data

The cosmopolitan assemblages in the lower part of the Hieroglyphic Beds do not permit a precise division into zones based on foraminifera. The foraminiferal assemblages were abundant, but the species of biostratigraphic significance occurred sporadically and only in single samples (Fig. 9). Planktonic foraminifera, although referred to the Early and Middle Eocene, occurred sporadically. In accordance with the principle of superposition, the age assessment of complex I points to the Ypresian–Lutetian. The assemblages of underlying deposits, in the uppermost part of the Ciężkowice Sandstone, were typical for the Rzehakina fissistomata Zone, known from the Palaeocene. The overlying deposits contained assemblages with *Ammodiscus latus* Grzybowski, referred to the Bartonian, or possibly to the late Lutetian (Fig. 9). The presence of cosmopolitan assemblages in a similar stratigraphic position was found in the Hieroglyphic Beds by Jurkiewicz (1976), who described "the assemblages of poor non-characteristic fauna" from the Silesian Nappe in an area more to the east. Geroch (1960) also reported the assemblages with forms of stratigraphic significance exclusively from isolated intercalations of variegated shales. The lack of index forms from the lower part of the Hieroglyphic Beds was also noted by Książkiewicz (1974).

In the middle part of the interval with the cosmopolitan fauna, the assemblages with great numbers of *Trochammina* occur and have the characteristics of monospecific assemblages. Their typical features include low diversity, and the presence of dwarf forms (Waśkowska, 2012). Studies on the small-sized *Trochammina* assemblages indicate that they de-

Fig. 10. SEM images of agglutinating foraminifera from the Stradomka section of the Hieroglyphic Beds. Scale bar = 100 µm. **A**. *Rhabdammina*/*Psammosiphonella* sp. with *Ammolagena clavata* (Jones et Parker), sample s. 105/76/09. **B**. *Rhabdammina*/*Psammosiphonella* sp. (s. 65/46/05). **C**. *Psammosiphonella cylindrica* (Glaessner), s. 53/50/05. **D**. *Rhabdammina*/*Psammosiphonella* sp. (s. 43/47/09). **E**. *Rhabdammina*/*Psammosiphonella* sp. with attached form of agglutinated foraminifera (s. 70/28/05). **F**. *Bathysiphon* sp. with *Ammolagena clavata* (Jones et Parker), s. 14/52/06. **G**. *Hyperammina* sp. (s. 43/47/09). **H**. *Ammolagena clavata* (Jones et Parker), s. 65/46/05. **I**{lang1033 . *Placentammina placenta* (Grzybowski), s. 45/30/06. **J**. *Placentammina placenta* (Grzybowski), s. 39/27/06. **K**. *Thurammina* sp. (s. 39/27/06). **L**. *Reophax plana* Halkyard (s. 65/46/05). **M**. *Reophax* sp. (s. 26/04/06). **N**. *Reophax duplex* Grzybowski (65/46/05). **O**. *Reophax duplex* Grzybowski (s. 26/04/06). **P**. *Pseudonodosinella elongata* (Grzybowski), s. 96/66/09. **R**. *Pseudonodosinella elongata* (Grzybowski), s. 64/58/05. **S**. *Subrepohax scalaris* (Grzybowski), s. 26/04/06. **T**. *Subrepohax scalaris* (Grzybowski), s. 26/04/06.


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veloped in the Silesian Basin during the Ypresian and their development reflected the specific conditions of sedimentation, which limited the development of more complex assemblages (Waśkowska, 2014a). The small-sized *Trochammina* assemblages have the structure of recolonising assemblages that functioned in deep-sea conditions after the Palaeocene–Eocene Thermal Maximum crisis (Waśkowska, 2012, 2014a). Their structure is reminiscent of the post-crisis *Glomospira* div. sp. assemblages, known from the Tethys.

Next, the Ammodiscus latus Zone *sensu* Olszewska, 1997 was distinguished. In the bottom part of complex III, an assemblage dominated by calcareous benthic foraminifera was found. A fairly numerous fauna of planktonic foraminifera (Fig. 9) contained species, such as *Subbotina angiporoides* (Hornibrook), *Acarinina medizzai* (Tourmarkine), and *Pseudohastigerina wilcoxensis* (Cushman and Ponton), together with *Globoturborotalia ouachitanensis* (Howe et Wallace) and *Globigerina officinalis* Subbotina that may co-occur from 44 to 42 Ma (age data after Pearson *et al*., 2006, and citations therein). In terms of its structure, the assemblage from sample 2/15/06 deviated markedly from typical assemblages occurring in the Hieroglyphic Beds. Its main components were calcareous foraminifera, which appeared sporadically in this part of the section, but their tests were fairly small and similar in size. Most of specimens did not exceed 300 µm, but some forms are larger. The state of preservation, in particular that of the delicate planktonic tests, was not good: they bore traces of corrosion. A particular feature is the carbonate content, which rises abruptly from several to 14% wt of rock (data from sampled layer), and then decreases again in the higher part of the section (Fig. 3). The difference in species and the structure of assemblages, as well as the state of preservation, indicate that it is a redeposited fauna. It was supplied in a suspension of carbonate mud from shallower areas. This process caused size segregation of the microfauna, connected with gravitational sedimentation in water. In thin sections, carbonate bioclasts, mostly fragments or, more rarely complete small tests of foraminifera were concentrated in the laminae enriched in allogenic quartz grains and laminae with small amounts of or a lack of quartz. The redeposited material was derived from late Lutetian calcareous mud that had accumulated on the slopes of the Silesian Ridge, on the southern margin of the Silesian Basin. Thus, the redeposited foraminifers were coeval with or older than deposition of the Hieroglyphic Beds. The redeposited late Lutetian fauna occurred within the deposits of the Ammodiscus latus Zone, of Bartonian age (Geroch and Nowak, 1984; Olszewska *et al*., 1996; Olszewska, 1997), although the absolute age of this zone is still undetermined.

The foraminiferal assemblages from the uppermost part of the Hieroglyphic Beds represented the Reticulophragmium gerochi Zone of the Priabonian (Geroch and Nowak, 1984; Olszewska *et al*., 1996; Olszewska, 1997). The diagnostic form, *Reticulophragmium gerochi* Neagu *et al*., is one of cosmopolitan foraminifera (Kaminski and Gradstein, 2005), but in the Outer Carpathians it occurs rarely, only in taxonomically diverse assemblages reflecting favourable life conditions.

The foraminiferal assemblage in the uppermost part of the section represents an autochthonous fauna. This is supported by the gradual increase in carbonates, resulting from palaeoenvironmental changes and the common occurrence of calcareous foraminifera and their taxonomic repeatability in samples from uppermost part of complex IV, as well as by the much better state of preservation. In complex IV, the calcareous foraminifera constitute a stable, although marginal component of the assemblage. Up the section, their number and diversity increased successively reaching an optimum in the Globigerina Marl. The foraminifera occurring in this part of the Hieroglyphic Beds indicate an age of 35 to 38 Ma, which corresponds to the Priabonian. The studies on the stratigraphy of the Globigerina Marl indicate that sedimentation of them took place from the end of the Eocene until the Oligocene (e.g., Blaicher, 1970; Olszewska, 1983, 1984; Leszczyński, 1997, and references therein).

Lithological variability of the Hieroglyphic Beds

The lithology of the Hieroglyphic Beds of the Szczyrzyc Depression is highly diverse.

The lower part (except for the basal part) exclusively consists of grey and grey-green shales without sandstones (complex I; Fig. 4). Their origin is connected with hemipelagic sedimentation. In thin section, they exhibited lamination deformed by bioturbation. The lamination is defined by the distribution of fine quartz grains.

These deposits, Lower Eocene in age, resemble the so-called “Green Shale”, which is a division associated with the Hieroglyphic Beds (e.g., Cieszkowski, 1992; Leszczyński and Radomski, 1994; Leszczyński, 1997; Waśkowska, 2014b). Although the Green Shale is situated in different stratigraphic positions, usually it overlies the thin-bedded flysch of the Hieroglyphic Beds and is chiefly Up-

Fig. 11. Images of agglutinating foraminifera from the Stradomka section of the Hieroglyphic Beds. Scale bar = 100 µm. **A**. *Pseudonodosinella* cf. *nodulosa* (Brady), s. 43/47/09. **B**. *Pseudonodosinella* cf. *nodulosa* (Brady), s. 45/30/06. **C**. *Pseudonodosinella nodulosa* (Brady), s. 90/42/05. **D**. *Ammodiscus latus* Grzybowski, s. 70/28/05. **E**. *Ammodiscus latus* Grzybowski, s. 26/4/06. **F**. *Ammodiscus latus* Grzybowski, 65/46/05. **G**. *Ammodiscus latus* Grzybowski, s. 70/28/05. **H, H1**. *Ammodiscus cretaceus* (Reuss), s. 96/66/09. **I**. *Ammodiscus cretaceus* (Reuss), s. 90/42/05. **J**. *Glomospira charoides* (Jones et Parker), s. 65/46/05. **K**. *Glomospira charoides* (Jones et Parker), s. 67/48/05. **L**. *Glomospira gordialis* (Jones et Parker), s. 65/46/05. **M**. *Glomospira gordialis* (Jones et Parker), s. 65/46/05. **N**. *Glomospira glomerata* (Grzybowski), s. 64/58/05. **O**. *Glomospira glomerata* (Grzybowski), s. 64/58/05. **P**. *Glomospira glomerata* (Grzybowski), s. 64/58/05. **R**. *Glomospira serpens* (Grzybowski), s. 64/58/05. **S**. *Glomospira serpens* (Grzybowski), s. 65/46/05. **T**. *Glomospira irregularis* (Grzybowski), s. 65/48/05. **U**. *Glomospira* cf. *irregularis* (Grzybowski), 65/46/05. **V**. *Glomospira* sp., s. 65/46/05. **W**. *Glomospira* sp., s. 65/48/05. **Y**. *Dolgenia* sp., s. 64/58/05. **Z**. *Dolgenia* sp., s. 64/58/05).


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per Eocene in age (e.g., Bieda *et al*., 1963; Geroch *et al.*, 1967; Geroch and Koszarski, 1988; Cieszkowski, 1992). However, they were not found in this stratigraphic position in the Szczyrzyc Depression.

The middle and upper part of the Hieroglyphic Beds – complexes II and IV – are developed here mostly as thin-rhythmic turbidites with an increase in carbonate content in the uppermost part (Figs 4, 5). The increased number of depositional events is marked by the occurrence of deposits connected with turbiditic currents bringing psammitic material to the sea floor. Intensification of the turbidity-current deposition occurred during Late Eocene times, when the deposits of complex IV were formed.

In the upper part of the Hieroglyphic Beds (Bartonian), the shaly-sandy deposits are separated by the shale complex III, 20 m thick. Its characteristic features are: the predominance of dark brown shales, interbedded with green shales, a small amount of sandstones, the presence of bentonitic layers and an increase in TOC up to 2% (Figs 3, 5, 8).

Black Eocene deposits

The deposits with the predominance of brown, dark brown, or dark-grey shale (locally even black) containing sandstone layers are marked in the Hieroglyphic Beds of the Silesian Nappe in the legends of a number of geological maps and in some lithostratigraphic studies (e g., Książkiewicz, 1951, 1974; Burtan, 1973; Cieszkowski, 1992; Szymakowska and Wójcik, 1992; Paul, 1993; Leszczyński and Radomski, 1994; Wójcik and Rączkowski, 1994; Cieszkowski *et al*., 2006a). The Middle Eocene age of some of these deposits was established on the basis of agglutinating foraminifera. The Middle Eocene dark deposits within the Hieroglyphic Beds were also documented in the Dukla Nappe, in the Cisna and Jaśliska areas (Ślączka, 1971, Ślączka *et al*., 1991).

In the Outer Carpathians, the most widespread Eocene dark deposits are known from the Fore-Magura group of nappes. Their characteristic features include the presence of brown shales with laminae of grey-green shales, as well as a subordinate number of brown sandstone beds with muscovite. These deposits were described from the Mszana Dolna Tectonic Window (Burtan, 1978; Cieszkowski *et al*., 1985; Cieszkowski, 1986), as well as from the Grybów Unit under the name of the Klęczany Beds (Olszewska, 1981; Połtowicz, 1985; Paul and Ryłko, 1987; Oszczypko and Wójcik, 1993). Additionally, they are known from drillings in the Obidowa-Słopnice Unit, where they are distinguished as the Rdzawka Beds (shale-sandstone flysch) with sandstones and conglomerates (the Zboj Sandstones; see Cieszkowski and Sikora, 1976, Jawor and Sikora, 1979; Cieszkowski, 1985, 2001; Cieszkowski *et al*., 1985) with a total thickness of up to 1300 m (Jawor and Sikora, 1979).

The age of the dark deposits is poorly documented, because of the absence of index fossils. In the Grybów Unit, the dark deposits were assigned to the Palaeocene–Eocene (Paul and Ryłko, 1987; Oszczypko and Wójcik, 1993), although only a Middle Eocene age is supported by foraminifers. In the Obidowa-Słopnice Unit and in the Mszana Dolna Tectonic Window, Gasiński *et al.* (1976), and Burtan (1978) indicate the Eocene age of the dark deposits, on the basis of the presence of *Reticulophragmium amplectens* (Grzybowski) in a taxonomically poor assemblage. Jawor and Sikora (1979) reported the Palaeocene–Eocene from Obidowa-Słopnice dark deposits based on the foraminiferal assemblages, containing *Rzehakina fissistomata* (Grzybowski) and *Reticulophragmium amplectens* (Grzybowski). However, the position and age of the Rdzawka Beds in the Obidowa-Słopnice unit is disputable. The lithology, thickness, and correlations of geophysical data indicate that they may be an equivalent of the Menilite Beds. The Lower Palaeogene fauna found there could have been redeposited by submarine flows, which are widely evidenced in the Rdzawka Beds. Contamination of sampling by a non-standard palaeontological procedure is also possible (Żytko and Malata, 2001).

In the references pertaining to the Carpathians, it has become customary to use the term “Black Eocene” for the Eocene dark deposits dominated by shales (e.g., Cieszkowski *et al*., 1985, 2006a; Cieszkowski, 2001, 1986, 1985). In principle, apart from the Rdzawka Beds, the remaining dark shales correspond in their lithology, position and age to complex III of the Hieroglyphic Beds of the Szczyrzyc Depression. Thus, the episode of sedimentation of dark deposits, enriched in organic carbon, was clearly marked within the Silesian Basin in the Middle Eocene. The concentration of organic matter in deep-water basins requires specific conditions and it is connected with a limited supply of clastic material in low-energy environments. The anoxic conditions caused the preservation of the organic matter, preventing the oxidation of carbon in the deposits.

The Black Eocene deposits in the Hieroglyphic Beds are easily distinguishable by their characteristic lithology with a predominance of dark shales. The first, thin layers of

Fig. 12. Images of agglutinating foraminifera from the Stradomka section of the Hieroglyphic Beds. Scale bar = 100 µm. **A**. *Paratrochamminoides heteromorphus* (Grzybowski), s. 105/76/09. **B**. *Trochamminoides* sp., s. 45/30/06. **C**. *Trochamminoides* sp., s. 45/30/06. **D**. *Trochamminoides proteus* (Karrer), s. 56/57/05. **E**. *Trochamminoides subcoronatus* (Grzybowski), s. 43/47/06. **F**. *Trochamminoides subcoronatus* (Grzybowski), s. 53/50/05. **G**. *Spirosigmoilinella* cf. *compressa* Matsunaga, s. 54/55/05. **H**. *Psamminopelta gradsteini* Geroch et Kaminski, s. 69/53/05. **I**. *Karrerulina conversa* (Grzybowski), s. 43/47/06. **J**. *Popovia beckmanni* (Kaminski et Geroch), s. 59/57/05. **K**. *Popovia beckmanni* (Kaminski et Geroch), s. 59/57/05. **L**. *Popovia beckmanni* (Kaminski et Geroch), s. 65/46/06. **M**. *Popovia beckmanni* (Kaminski et Geroch). **N**. *Arenobulimina dorbignyi* (Reuss), s. 96/55/06. **O**. *Ammogloborotalia* aff. *subvesicularis* (Hanzlikova), s. 1/str/05. **P**. *Ammogloborotalia* aff. *subvesicularis* (Hanzlikova), s. 1/str/05. **R**. *Ammomarginulina aubertae* Gradstein et Kaminski, s. 1/str/05. **S**. *Trochammina* cf. *umiatensis* Tappan, s. 90/42/05. **T**. *Trochammina* cf. *globigeriniformis* (Parker et Jones), s. 40/36/05. **U**. *Trochammina* cf. *globigeriniformis* (Parker et Jones), s. 40/36/05. **W**. *Trochammina* sp., s. 40/36/05.


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dark shales appear occasionally within the grey-green deposits, in the upper part of complex II, and occur up to complex IV (Fig. 5). The next dense complex of dark deposits, classified as the Menilite Beds, is located above the Globigerina Marl. Below the Globigerina Marl, in the uppermost part of the Hieroglyphic Beds, Upper Eocene dark shales of the Menilite-type occur interbedded. Although deposits of the Black Eocene are clearly separated from the dark Menilite-type deposits by a section of grey-green shales with sandstones belonging to complex IV, more than 40 m thick. A similar succession is observed in the Hieroglyphic Beds section of the Beskid Mały Mountains (Książkiewicz, 1951).

Subaqueous mass movements

Within the Lutetian deposits (complex II), a submarine slump occurs (Fig. 3). The redeposited material consists exclusively of shales and sandstones, which were derived mostly from the Hieroglyphic Beds. However, clasts from the Istebna Beds were also recognized. The material is mixed; it was most probably deposited during a single episode of mass movement.

Evidence of subaqueous mass movements on a small scale was observed in the Bartonian deposits in the lowermost part of complex III, where the carbonate shale with abundant, calcareous foraminifers is present. It is sandwiched in thick non-calcareous deposits and contains a unique foraminiferal assemblage. This uniqueness is expressed in the taxonomical composition and amount of calcareous forms, typical of much shallower environments.

The subaqueous mass movements in the Hieroglyphic Beds are associated with the final phase of the second stage in the evolution of the Carpathian basins (Cieszkowski *et al*., 2011). They were initiated during one of the major thrusting pulses of regional tectonic development in the Outer Carpathian accretionary prism, when ridge-bounded elongate synclinal basins were formed and underwent deep subsidence (Cieszkowski *et al*., 2009, Waśkowska and Cieszkowski, 2014). Some incidental redeposition occurred in the Silesian Basin at that time (Cieszkowski *et al*., 2009; Waśkowska and Cieszkowski, 2014).The largest olistostrome in the Hieroglyphic Beds of the Silesian Nappe is described from the Rożnów Lake area, situated to the east of the Szczyrzyc Depression (Cieszkowski, 1992; Cieszkowski *et al*., 2010; Waśkowska and Cieszkowski, 2014).

CONCLUSIONS

The Hieroglyphic Beds within the Szczyrzyc Depression, about 180 m thick, occur in a standard stratigraphic position for the sedimentary succession of the Silesian Nappe, i.e. between the Ciężkowice Sandstone and Globigerina Marl. They were subdivided on the basis of lithology into four complexes: of: I – green shales, II – green shales with sandstones, III – brown and green-grey shales with bentonites, and IV– grey-green shales with sandstones, calcareous at the top. The Green Shale below the Globigerina Marl, known from the other regions of the Silesian Nappe, does not occur.

The deposits of complex III consist of dark shales and mudstones with intercalations of grey-green shales and contain numerous bentonitic laminae. These deposits are the richest in organic carbon (1–2% TOC). They are dated to the early Bartonian (lower part of Ammodiscus latus Zone) and can be assigned to the so-called Black Eocene, which is known from the Fore-Magura group of nappes at the same stratigraphic position.

During the sedimentation of the Hieroglyphic Beds, there was an episode of subaqueous mass movement and resedimentation in the Middle Eocene. A submarine slump (complex II), 10 m thick, contains rocks from the Hieroglyphic Beds and the Istebna Beds. The resedimentation is marked by a unique foraminiferal assemblage with rich calcareous planktonic and benthic forms and high carbonate content in the shales. The episode of mass movements coincided with the second phase of geotectonic reorganization of the Carpathian basins.

The age of sedimentation of the Hieroglyphic Beds was established on the basis of commonly occurring agglutinating foraminifera. The Hieroglyphic Beds of the Szczyrzyc Depression were deposited from the early Ypresian until the Priabonian. Between the Ypresian and Bartonian, assemblages of cosmopolitan foraminifers were developed, with a late-Ypresian interval when small-sized *Trochammina* predominated (complexes I, and II). Next, the Bartonian Ammodiscus latus Zone (complexes II, III, and IV) and the Priabonian Reticulophragmium gerochi Zone (complex IV) were distinguished.

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Fig. 13. Images of agglutinating foraminifera from the Stradomka section of the Hieroglyphic Beds. Scale bar = 100 μm. **A**. *Eratidus gerochi* Kaminski et Gradstein, s. 59/57/05. **B**. *Eratidus gerochi* Kaminski et Gradstein, s. 59/57/05. **C**. *Buzasina pacifica* (Krasheninnikov), s. 69/53/05. **D**. *Buzasina* galeata (Brady), s. 69/53/05. **E**. *Buzasina pacifica* (Krasheninnikov), s. 65/46/05. **F**. *Reticulophragmium gerochi* Neagu *et al*., s. 64/58/05. **G**. *Reticulophragmium gerochi* Neagu *et al.*, s. 64/58/05. **H, H1**. *Reticulophragmium amplectens* (Grzybowski), s. 53/50/05. **I, I1**. *Reticulophragmium amplectens* (Grzybowski), s. 64/58/05. **J**. *Reticulophragmium amplectens* (Grzybowski) with *Ammolagena clavata* (Jones et Parker), s. 67/48/05. **K**. *Haplophragmoides nauticus* Kender, Kaminski et Jones, s. 9/54/06. **L**. *Haplophragmoides nauticus* Kender, Kaminski et Jones, s. 53/50/05. **M**. *Haplophragmoides stomatus* (Grzybowski), s. 90/42/05. **O**. *Haplophragmoides kirki* Wickenden, s. 59/57/05. **P**. *Haplophragmoides* cf. *horridus* (Grzybowski), s. 90/42.05. **R**. *Haplophragmoides parvulus* Blaicher, s. 64/58/05. **S**. *Recurvoides* sp., s. 26/04/06). **T**. *Recurvoides walteri* (Grzybowski), s. 64/58/05. **U**. *Recurvoides walteri* (Grzybowski), s. 39/27/06. **W**. *Eggerelloides propinqus* (Brady), s. 27/26/06.


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Fig. 14. SEM images of calcareous foraminifera from the Stradomka section of the Hieroglyphic Beds. Scale bar = 100 μm. **A.** *Subbotina yeguaensis* (Weinzierl et Applin), s. 105/76/09. **B**. *Subbotina yeguaensis* (Weinzierl et Applin), s. 96/66/09. **C**. *Subbotina* cf. *linaperta* Finlay, s. 96/66/09. **D**. *Subbotina* cf. *linaperta* Finlay, s. 96/66/09. **E**. *Subbotina linaperta* Finlay, s. 96/66/09. **F**. *Subbotina corpulenta* (Subbotina), s. 96/66/09. **G**. *Subbotina corpulenta* (Subbotina), s. 96/66/09. **H**. *Subbotina corpulenta* (Subbotina), s. 96/66/09. **I**. *Subbotina crociapertura* Blow, s. 2/15/06. **J**. *Pseudohastigerina wilcoxensis* (Cushman et Ponton), s. 2/15/06. **K**. *Subbotina* sp., s. 2/15/06. **L**. *Subbotina* sp., s. 2/15/06. **M**. *Acarinina medizzai* (Tourmarkine), s. 2/15/06. **N**. *Acarinina medizzai* (Tourmarkine), s. 2/15/06. **O**. *Globoturborotalia ouchitanensis* (Howe et Wallace), s. 2/15/06. **P**. *Acarinina bullbrooki* (Bolli), s. 2/15/06. **R**. *Acarinina* cf. *collactea* (Finlay), s. 2/15/06. **S**. *Mucronina* jarvisi (Cushman et Todd), s. 2/15/06. **T**. *Dentalina* sp., s. 96/66/06. **U**. *Globocassidulina subglobosa* (Brady), s. 2/15/06. **V**. *Cibicides westi* Howe, s. 2/15/06. **Y**. *Gyroidinoides girardanus* (Reuss), s. 98/68/09. **W**. *Oridorsalis umbonatus* (Reuss), s. 2/15/06. **Z**. *Globocassidulina subglobosa* (Brady), s. 2/15/06.

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